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GREENHOUSE REMOTE MONITORING & CONTROL SYSTEM

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By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Department of Electrical & Electronic Engineering
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Approved:

____

Your Supervisor's Name
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

September 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Hairil Hafizi Bin Mohd Hashim

ABSTRACT

Continuous control and monitoring of the greenhouse factors can be considered as a pivotal part in the production practices. The rate of crop's growth highly influenced by the surrounding optimal climate conditions, but in order to do so, they required sets of expensive and complex equipment. Conventional systems used an excessive work to link and dispense the transducers and their control systems. One of the reasons why it's expensive is the requirement of the systems of having a wide range of power wires and data cables to and from the sensors to control systems. Plus, for users such as growers and planters for businesses are having difficulties to monitor and control its system from any remote location with the system applied only allowed to be control from the control room and et cetera. To overcome these drawbacks, this proposal intends to describe how the innovative greenhouse control system can be characterized as an event-based system, where every control actions are primarily deliberated compared to the events formed by instabilities from surrounding elements. Proposed control system offers a costs-saving solution with low maintenance required, as well as producing a great performance results. This solution also with eliminate the over-dependability of the industry to the human workforce today.

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Greenhouse is a structure, normally built from glass or clear plastic, where crops are grown inside it. Greenhouse's main task is to offer a protective environment for the crop production while allowing natural light transmission [1]. Based on that statement, the greenhouse management system helps to control the crucial parameters inside it. In Malaysia, greenhouse technology also applicable and the most common application are located in Cameron Highlands Agrotechnology Park. The types of plants growing in the greenhouse are apples, strawberries, pears, persimmons, roses, tomatoes, and others. These sorts of plants need cool temperature with medium humidity to be able to grow perfectly.

Due to high humidity and hot weather year-in year-out in Malaysia, it is very hard to plant crops such as per mentioned above. Thus, the greenhouse technology is certainly applicable to achieve such objectives in Malaysia. Beside here, the technology is much more common in the western countries, where due to the changes of the seasons; make it they have to apply the technology to control the surroundings. For instance, the lilac bushes that are normally grown in Holland using the greenhouse technology to increase the productivity thus are increasing their profit [2].

The control of greenhouse climate, in order to improve the development of a specific cultivation and to minimize the production cost becoming increasingly important for the growers [3]. In the last several decades, systems for greenhouse management have been greatly developed, in which kinds of sensors have been used to measure various information of the environment [4]. Conventional management systems have mostly improved based on the wired method. With the wired method, the installation of the system is relatively easy with extension option and increased the maintenance costs of the wiring. Plus, with big greenhouse, it will require a lot of wires to complete a control system.

Typical greenhouse control systems monitored mainly the environment elements such as the temperature and humidity inside the greenhouse. These are the important data as the growth of plants is highly affected by them. However, to be able to monitor a details crop grow status requires more accurate and various data than temperature and humidity only. Accordingly, monitor crop itself is as important as monitoring indoor environment [4].

1.2 Problem Statements

Most of the greenhouses in Malaysia today still rely on the human manpower to maintain the facilities without proper control system. Manpower is prone to error. To run the plant efficiently, a control system has to be apply that can simultaneously reduce the cost of operation, without having to rely too much on the manpower. It also can improve the production of the plants, hence increase the profit of the organization. Besides, as Malaysian climate is categorized as equatorial, with hot and humid condition throughout the year, this application will enable the crops to grow in perfect condition, and increase the productivity without having to depend on the weather and environment conditions naturally.

1.3 Project Significance

The significant of this project is it is closely associated to the field of instrumentation and control, one of the major offered under Electrical & Electronics Department at UTP. It is my interest, and I would like to apply my knowledge in the field and challenge myself to conduct the project as best as I can. The project also related to the important issue in the world today; global warming. The world has been relying on non-renewable energy and causing the average temperature of the earth rising up since. With the application of the technology like the greenhouse, somehow it can help to maintain the balance of the global warming now, either directly or indirectly.

1.4 Objectives

The objectives of the project are:

a) To develop a remote controlling and monitoring system for greenhouse applications.

b) To understand the working principle of typical greenhouse control system and its main parameters.

c) To provide an effective solution to the existence problem related to the greenhouse control system technology by applying tools and techniques of problem solving.

d) To apply tuning methods to the controller, and analyze the results to come out with the best controller's configuration.

1.5 Scope Of Study

The scope of study for this project will be mainly related to the application of effective control system to the greenhouse, but not just limited to it. Various control system methods will be applied, and the comparisons between those methods will be analyzed and discussed in order to identify the best solution that met the objectives. The techniques learnt while in classes and during internship will be applied to produce the accurate and consistent result. Analysis of the results will be conducted at the end of the project, so that the project can be concluded as meeting the objectives or not. Suggestion and recommendations to improve the project from all aspect will be identified. There are limitations to the project that beyond the reach of me.

1.6 Feasibility Study

The project will be based on small-scale greenhouse control system that will replicate a real-world situation. The components and devices use in this project may be not as per what shall be applied in the real-world environment, but enough to make sure that the objectives in met and proved. In completing this project, there are several constraints that need to be aware of, such as:

1.6.1 Time.

The time given to complete final year project (FYP) is two 14-weeks semesters. At the end of the period given, a detail presentation will be conducted, and submission of final report to the coordinator. In order to meet the objectives in time, the project will be focused a selection of important features only. The type of plants chosen also is crucial to prove the effectiveness of the applied system.

1.6.2 Budget

Due to the budget limitation, the selections of devices also need to be considered thoroughly. The choice of crucial elements such as DAQ card, LabVIEW software and sensors will be based on the budget given, with priorities to achieve the best solution and met the objectives.

CHAPTER 2

LITERATURE REVIEW

2.1 Greenhouses

A greenhouse is a structure covering ground frequently used for growth and development of plants that will return the owner's risk time and capital [5]. The main purposes of the usage of greenhouses are to protect crops from extreme conditions and provide them better environment for efficient production. Unlike the conventional agriculture, where the conditions of the crops depends on the environment in the surrounding, greenhouse control the environments parameters such as temperature, humidity, water and light intensity to give the crops perfect conditions to grow. With better environment, the quality of the crops will be much better and will increase the profit for the seller. However, to achieve the purposes stated and to have a better control in horticulture development, a control system with monitoring features is being applied. Normally the temperature maintained on daytime is different compared to temperature falls at night. Besides, it varies with the condition of the weather itself either it is cloudy or sunny day. This assumes that the temperature at which the plants grown can actually be controlled [6].

Even though the implementations of greenhouse protect the crops from unwanted elements, it still can cause several other problems such as fungus and excessive humidity. This is due to the structure of the greenhouse itself. Therefore, the application of control system with constant monitoring is very crucial to the greenhouse to achieve the best productivity and quality. With better control, the cost of operations can be reduced with minimal workers needed and controlled usage of raw materials such as water, soil and fertilizer.

The main elements involved a greenhouse control system are temperature, humidity, CO_2, concentration, radiation, water and nutrients [5].

While these elements feature separately in the environment, they are related and influence each other. The heating requirements of a greenhouse rely on the desired temperature for the plants grown, the location and construction of the greenhouse, and the total outside exposed area of the structure. As much as 25% of the daily heat requirement may come from the sun, but a lightly insulated greenhouse structure will need a great deal of heat on a cold winter night. The heating system must be sufficient to maintain the desired day or night temperature. Regularly the home heating system is not ample to heat a neighboring greenhouse. Small gas or oil heaters designed to be installed through a masonary wall may work well [7].

Installing circulation fans in the greenhouse is a good venture. During the winter when the greenhouse is heated, the air circulation needs to be sustained so that the temperature remains uniform throughout the greenhouse. Without air-mixing fans, the warm air rises to the top and cool air settles around the plant on the floor. Ventilation is the interchange of inside air for outside air to control temperature, remove moisture, or replenish carbon dioxide. Regular ventilation uses roof vents on the ridge line with side inlet vents. Warm air rises on the convective streams to outflow through the top, drawing cool air in through the sides. Mechanical ventilation uses an exhaust fan to move air out one end while outside air enters the other end [7].

Water supply into the greenhouse is one of the important aspects of the system. In the conventional system, hand watering is the only possible way to keep the plants receive sufficient amount of water at times. This uses lot of manpower, and time. If the greenhouse have a variety plants in it, each plant may need different amount of water, and soil mixes and else. Currently, there are several methods of semi-automatic system available to conduct the task in a set time. Sprinkler is a popular method, with the covering area is big enough but with no automatic system for different plants. Time clocks and moisture evaporation can be used to stop the sprinkler and create an automatic system.

2.2 Control System

Control system consists of subsystems and processes assembled for the purpose of obtaining a desired output with desired performance, given a specific input. Two major measures of performance are apparent; the transient response and the steady state error [8]. These parameters are shown in the Figure 1.

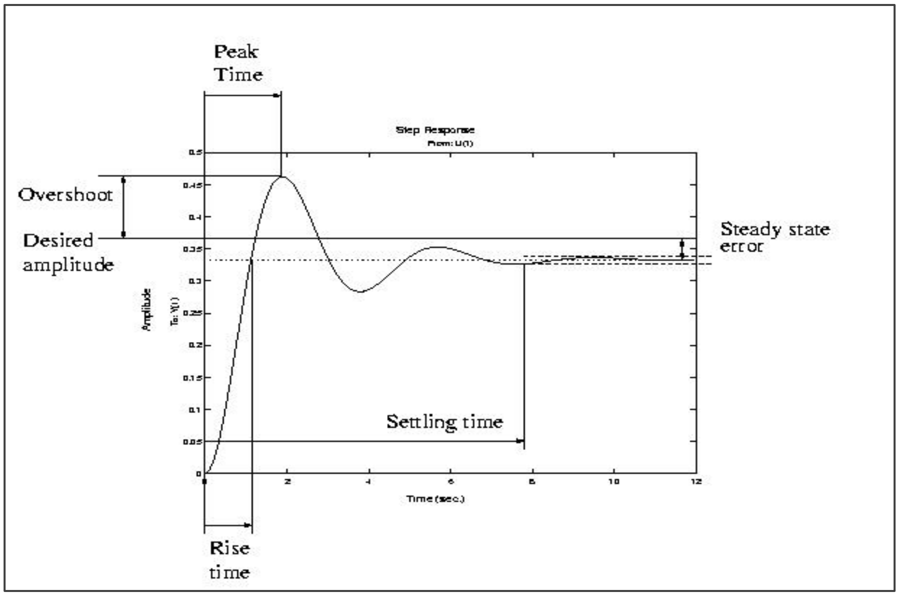


Figure 1: Output response of a control system

There are two major configurations of control systems; open loop and closed loop. The disadvantages of open-loop systems namely sensitivity to disturbances and inability to correct for these disturbances, it can be overcome in closed-loop systems. This configuration compensate for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction. If there is any error between the two responses, the system drives the process, via actuating signal to make a correction. Closed-loop systems have the obvious advantage of greater accuracy than open-loop systems. They are insensitive to noise, disturbances and alterations in the surroundings. Transient response and steady-state error can be controlled more conveniently and with greater flexibility [8].

A control system is dynamic as it response to an input by undergoing a transient response before reaching a steady-state response that generally resembles the input. The transient response is important because it affects the speed of the system to settles and influences human patience and comfort. Steady-state response determines the accuracy of the control system and governs how closely the output matches the desired response [8]. Example of closed-loop system block diagram depicted in Figure 2.

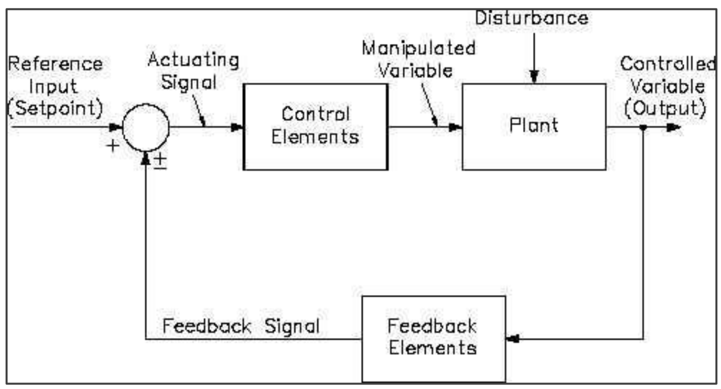


Figure 2: Closed-loop system block diagram

In order for us to continuously control and monitor all the parameters such as temperature, humidity, CO_2, concentration, and water, sensors and actuators that can measure and control the desired values will be used. Largely, the control system of the greenhouse is implemented with approximating measured values to the respective desired values as close as possible or better known as setpoint, shown in Figure 3.

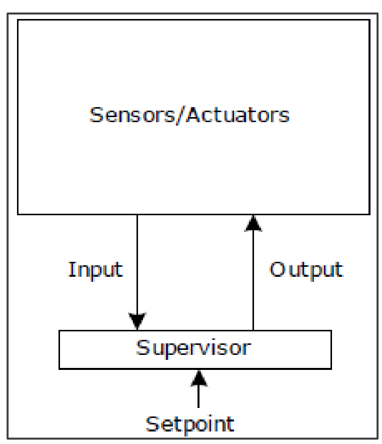


Figure 3: Typical control system

Automatic monitoring system involves the installation of monitoring units that will automatically collect values from the field and transmits it into a centralized unit in the control room. Automatic monitoring can be programmed to monitor various items regarding the plant [9].

In control system, all the sensors in the field will continuously sending inputs of measured variables to the central system, acting as the brain of the system. The central systems then will give the outputs to the control elements to manipulate the measured variables to bring them as close as possible to the desired values. Distributed Control System (DCS) and Supervisory Control and Data Acquisition (SCADA) are the control systems available for this application. Both DCS and SCADA are control and monitoring mechanism that are used in the industrial applications in order to control the processes within specified limit. DCS is more to process-oriented system, as its focus more on the processes in each step of the operation. DCS complete all the tasks required in sequential manner. In terms of applications, DCS is the preferable choice of system for installations for a limited location of industry, like a small plant or factory. This is mainly because the operations of DCS required for the system to always connect to its inputs and outputs at all time.

SCADA, in the other hands focuses more on the data acquisition, collection and record all the parameters for future uses. This system is based on the event-oriented, where a change of value in a parameter will trigger certain actions. This feature lightens the load of the system. SCADA is suitable for applications where the entire system is spread across a large location or space. SCADA can perform even when there are communication failures in the system by keeping record all the current values so that it’s able to present the last recorded values to the current operations.

2.3 Data Acquisition Card and LabVIEW

Data acquisition (DAQ) is process of measuring electrical or physical entities such as voltage, current, temperature, pressure or sound with a computer. Complete systems of DAQ consist of transducers, DAQ hardware and computer with programmable software compatible with the hardware, shown in Figure 4. Compare to conventional method of measurement systems, DAQ systems uses the processing power, productivity, display and connectivity to provide more powerful, flexible, and cost-effective measurement solution.

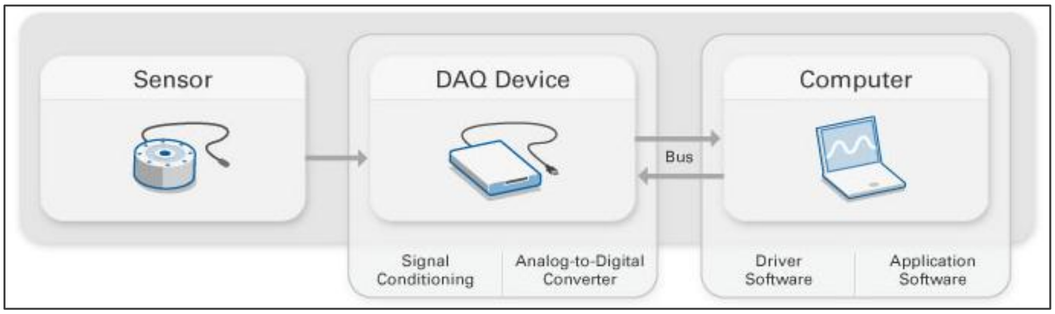


Figure 4: Block diagram of DAQ system

Transducers, or more commonly called sensors convert a physical portent into a more measurable electrical signals. The signal can be either in voltage, current, resistance or others electrical attributes. The DAQ device is the link between the sensors and transducers and a computer with the programmable software. It main function is to convert the entire electrical signal from the sensors and transducers to digitize form so that it can be interpreted by the computer and its software. In this equipment, there are three main components which are the signal conditioning circuitry, analog-to-digital converter and the bus. The computer controls the overall operation and used for processing, visualizing and storing the measurement data.

Lab Virtual Instrument Engineering Workbench (LabVIEW) is graphical programming software suitable for developing automated instrumentation system, compatible with DAQ boards. It has been widely adopted throughout industry, academia, and research labs as the standard for data acquisition and instrument control software. LabVIEW is a powerful and flexible instrumentation and analysis software system that is multiplatform – you can run LabVIEW on Windows, Mac OS X, and Linux [10]. It's mainly used for engineering data acquisition, analysis and presentation. It computerized the measurement of real world analog signals and generation of the signals. LabVIEW departs from the sequential nature of traditional programming languages and features and easy-to-use graphical programming environment, including all of the tools necessary for DAQ, analysis, and presentation of results. With its programming language, sometimes called "G", it can be programmed using a graphical block diagram that compiles into machine code [10].

2.4 Controller Tuning Methods

Before the system been applied to the application, it must been tested and tuned first. There are many tuning methods that are available, and some of them are the popular and mostly used to tune control loops. The loop to be tuned must be completely connected with the controller, final control element and the sensor. If possible, the surrounding and environment of the tuning to be carried out also need to be as per its intended purpose. This is in order to eliminate the error during the tuning and calibration, and also to make sure that the loops been tuned efficiently.

Basically, tuning methods can be categorized into two parts; open-loop and closed-loop. In open-loop tuning methods, it's being conducted in manual mode of the controller, meaning that the step input is manipulated in order to produce the process reaction curve of the control loop. Whereas, closed-loop tuning methods is conducted during the mode of the controller is in automatic mode, which will apply the parameters of the controller to produce reaction response of the process.

Among the open-loop tuning methods available, Ziegler-Nichols is the most popular and widely used in the industry nowadays. This technique modeled the process dynamic by applying a first order plus dead time (FODT) model. This technique will analyze the characteristic of the process reaction curve to enable the calculation for the parameters to be made. Another popular technique in open-loop tuning methods is the Cohen-Coon method. In this method, the process reaction curve obtains as per usual before the process dynamic being approximated by the FODT. As per Ziegler-Nichols, the characteristic of the curve will be used to calculate the parameters for the controller.

From the closed-loop methods, the most known and widely used technique is Ziegler-Nichols closed-loop technique. This technique is also known as online or continuous cycling or ultimate gain tuning method. This technique will manipulate the value of proportional gain, K_c in order to determine the desired response, hence defined the ultimate gain, K_u and ultimate period, T_u. Main reason of this technique's popularity is this technique does not require the process model of the system in order to tune the controller. Despite the advantage, this technique also has several disadvantages such as time consuming and not suitable for processes that is unstable in open-loop condition.

2.5 Past Related Projects

A new greenhouse climate control system has been constructed back in 2003 with the objective of decreasing energy consumption while maintaining, or even increasing, plant production [11]. The program called IntelliGrow, consists of a personal computer and a greenhouse environment control computer. It used Delphi 5 as software and the programming language. The project uses mathematical models to estimate the parameters measured such as absorption of irradiance, leaf photosynthesis, and respiration. The room temperature being controlled depending to the natural irradiance, and allow to vary considerably more than in a standard climate. Energy used for this system was reduced under the low light conditions because of the low surrounding temperature. When the irradiance is higher, the system is capable of utilizing the high temperature and

CO_2. The system able to balances the energy costs saved via the isolation against the production loss caused by the decrease in irradiance. Six-month trial using this system resulted total energy saving ranging from 8% to 40%.

A distributed greenhouse control system based on LonWorks technology is presented in a project called Application of LonWorks Distributed Control Technology in Greenhouses, where the processing and communication connections are distributed among the components of the system, called nodes. The proposed greenhouse control system architecture is robust and flexible, allowing the development of a great variety of systems, from simple to complex one, which will be useful to implement flexible experiments. Unlike typical hierarchical systems, control network based systems are more robust: they can operate even the supervision microcomputer is disconnected or some node is damaged (in this case with performance degradation) [12] .

Other related works are shown in a project called Wireless Sensors in Agriculture and Food Industry, where some applications using wireless sensors, including greenhouse control are presented. In these applications, technologies such as WLAN, Bluetooth and RF transmission are presented. Examples of wireless sensors and sensor networks applied in agriculture and food production for environmental monitoring, precision agriculture, M2M-based machine and process control, building and facility automation and RFID-based traceability systems are given. The project also evaluates the advantages of wireless sensors and obstacles that prevent their fast adoption [13].

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.1 Research Methodology

The project's objective is to develop a remote controlling and monitoring system that allowed operators or users to continuously control and monitor the plant from a distant location. With the application of the system, it will help to save time, manpower for tasks, cost of production and safety of the workers.

The project utilized LabVIEW to create the SCADA system and act as a link for the system to the internet. In order to run a real-time system, a prototype model of greenhouse plant will be hooked-up to the LabVIEW via a DAQ card. The greenhouse contains parameters that able to be measured continuously with equipment to control them.

A thorough research was done through the internet and from the books from Information Resource Centre (IRC) on the greenhouse technology and control system methods. Final reports from previous final year project students were also referenced to analyze the format and standard used to complete the project documentations.

As for summarization for the entire project, a process flow chart as in Figure 7 produced. Each step and stage of the project is able to be tracked based on the flow chart.

3.2 Project's Working Principles

Basically, the project is measuring continuously the important parameters for the greenhouse. In this part of the report, the details of each control system will be explained.

3.2.1 Temperature Control

Temperature plays an important aspect of greenhouse control system as some crops required the environment's temperature to grow maturely. So, for this project, the temperature will be applied with linear, PID control system, as illustrates in Figure 5. A setpoint (35 Degree Celsius) will be set at the controller, as the desired value of the temperature that suitable for the plants in the greenhouse. The final control element of this loop will produce heat into the greenhouse, based on the analog signal sent from controller in order to reach the setpoint required. The process variable, room temperature of the greenhouse will be measured using a thermistor, a type of sensor. The signal from the sensor will be feedback to the controller back. This analog signal will be compared with the setpoint by the controller, so that corrective signal can be sent to the final control element to regulate the temperature.

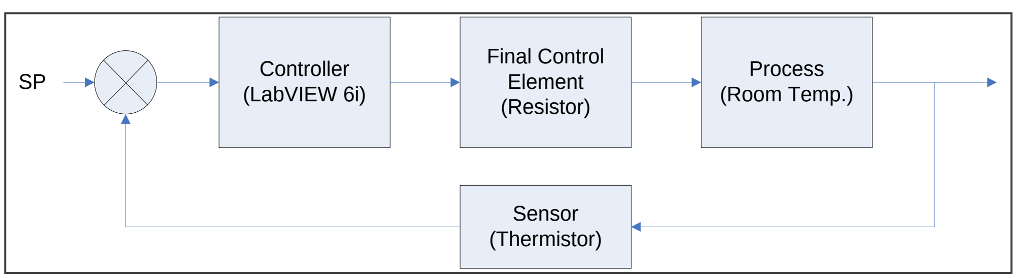


Figure 5 : Temperature control loop

The signal out from the controller and in from the signal will be in analog form of 0-10 Vdc. The reason why PID controller is use in this loop is to achieve the setpoint in the fastest way possible, without having to much offset and the temperature can be regulated in a way that a change in the setpoint would not disturb the control system. The process variable can follow the setpoint smoothly. The control loop also needs to be able to overcome the disturbance issue that may present in the hardware. The loop will equipped with an alarm setpoint, so that if the room temperature reached the temperature, due to the maybe malfunction of the equipment, that can damage the plants inside, it will trigger an alarm to notice the operator.

3.2.2 Light Intensity Control

Light can be controlled in the greenhouse control system for many purposes. Light helps the crops for the process of photosynthesis, where the plants will emit oxygen to the air. Light also influence the heat loss in the greenhouses between the temperatures inside and outside of the house, and the evaporation of water inside the greenhouse. Due to its major role, light intensity will be controlled continuously in the project. The control loop block giagram shown in Figure 6.

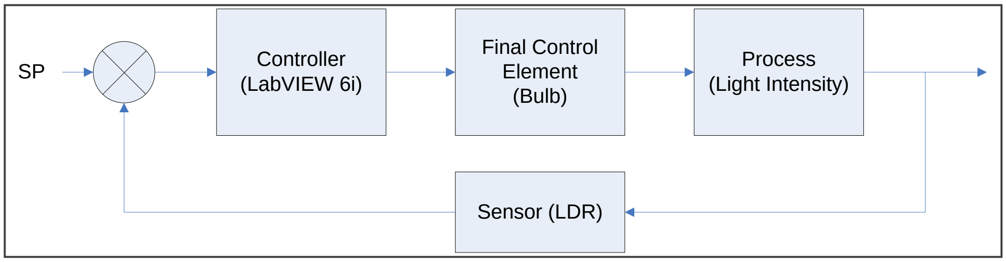


Figure 6 : Light intensity control loop

A setpoint, the intensity which will be the best for the process photosynthesis, set in the controller’s input for the controller to determine the sufficient signal to be sent to the bulb, this loop’s final control element. There will be a light dependent resistor (LDR) as sensor that will determine the light intensity inside the greenhouse. The analog signal from LDR will be transmitted into the controller; to be compared with setpoint before corrective signal can be sent to the bulb.

3.2.3 Others

There are other several parameters that worth measuring in order for us to further understand the behavior of major parameters in reacting to any changes in the surrounding. These parameters also can be the disturbances in the system. By measuring them, we can analysis and improve the system more in the future.

- Outside temperature

  Temperature outside of the greenhouse is considered as major disturbance to the temperature control loop. The temperature difference during midday and night is big and the performance of the control system has to be in optimum condition. With this, we can determine the relationship between the temperatures inside and outside of the greenhouse.

- Water level

  Water is a must in growing crops, but it sometimes can be a disturbance too. Water can absorb heat easily and influenced the room temperature heavily. Water level and flows will be monitored and HI and LO alarms will be equipped for safety purposes.

- Humidity

  The humidity level for the crops is important feature in the greenhouse. Too high level of humidity could encourage the diseases for the crops that can damage the plants. Humidity also changes from day to night instantly. Humidity can be balanced by having a circulation fan in and out from the greenhouse. The fan will be activated at night to reduce the humid air inside the house.

3.3 Expected Results

At the end of the project, several results are expected from the project's working principle point of view. The system shall be able, at any conditions whatsoever, to keep the process variables as close as possible to the setpoint set at early stage of the project, or in the other word stable. With the present of disturbances in the system such as changes in environment whether and so on, the controller shall be able to compensate these disturbances without having to affect the process variables. The response time of the system to eliminate the error has to be justified, short with low overshoot. The controller also needs to be able to react to any changes in input and send appropriate signals to the control variables to eliminate steady-state error after changes has been done. This shows the robustness of the system implemented.

Several tuning techniques will be applied to determine the best solution for the system. Tuning techniques applied, such as Ziegler-Nichols, Cohen-Coon, and Ciancone has its very own advantages and disadvantages, as per discussed in the Literature Review section. Some of the parameters are not suitable for slow or fast processes respectively, and that will be taking into account in carrying the experiments to produce the best configuration for the controller later.

3.4 Project Activities

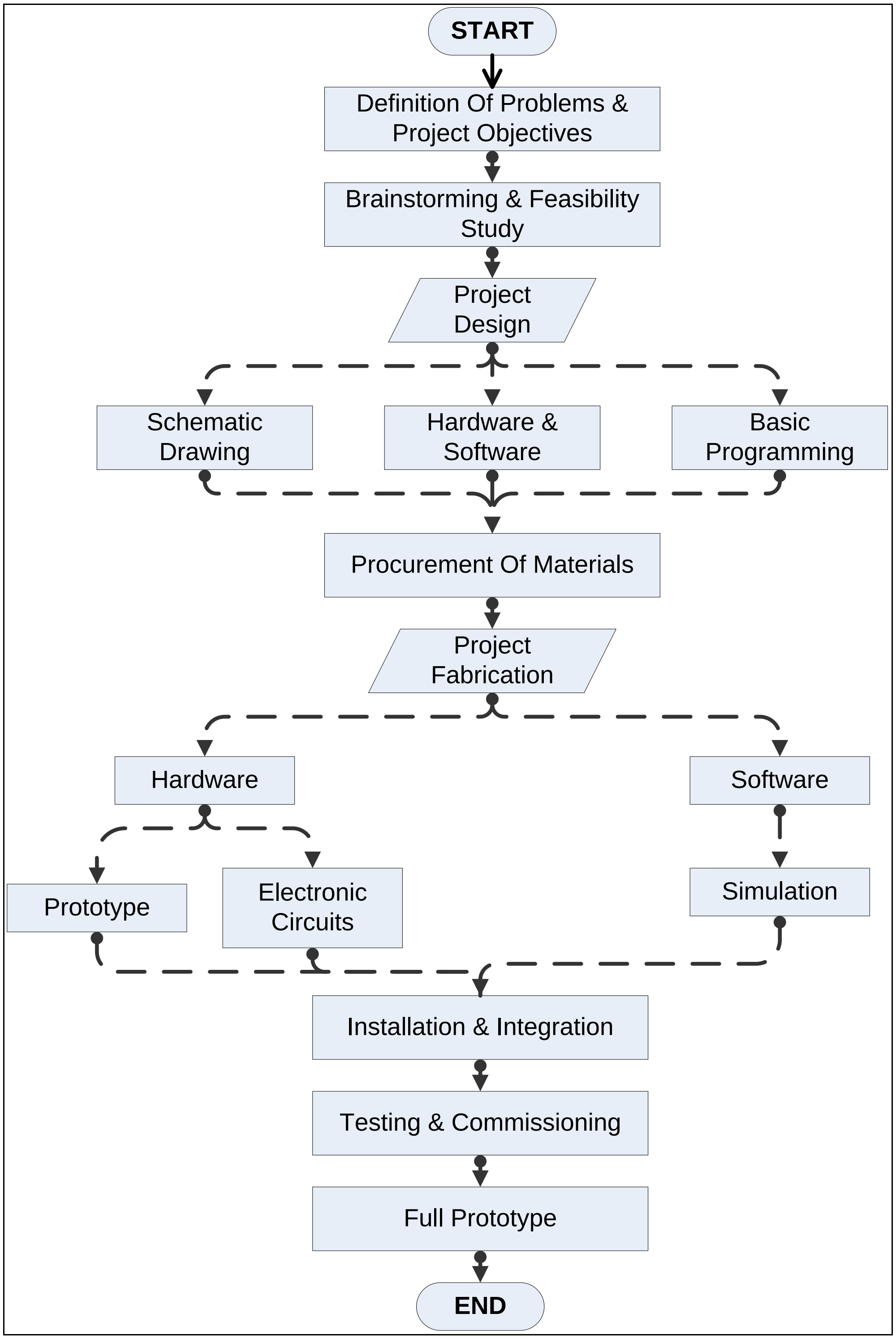


Figure 7: Flow chart for the project

The project started with the identification of a problem that want to be solved and it definition. The problem shall be crucial and important. The definition must be around the problem statement and based on the real life situation. Here, once the problem being chosen with the definition, solutions to the problem must be created and suggested. The solution can be found during a brainstorming process of the project. During this stage, feasibility study being conducted in order to know the project-related information available over the world. The ability to analyze projects that have similar objectives is also crucial in this part. Solutions for others projects must be considered and improvise for the project to ensure the objectives is achieved.

Upon completing the brainstorming and feasibility study, designing the project is the next step. With the information from the data gathered in previous stage, the project can be divided into three different parts; hardware and software selection, schematic drawings, and basic programming. The hardware and software need to be select based on the project requirements to achieve the objectives. It also needs to be based on the time frame given and budget for the project. Software chosen must be able to communicate with the hardware and compatible to each other. The schematic drawings are for the electronic circuits that need to be constructed. The circuits mainly constructed for the sensors, control elements and inputs and outputs from and to the software. The basic programming is the heart of the control system. The software requires the program to run the system, as per desired by the user.

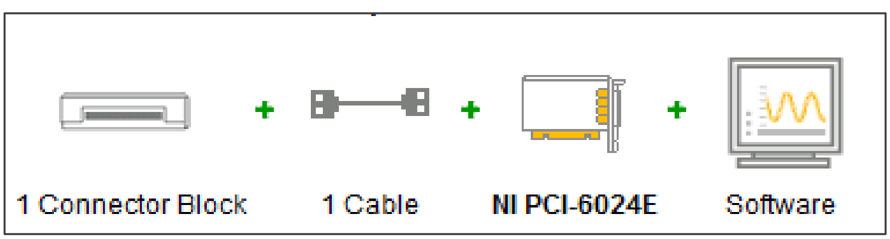


Figure 8: Typical DAQ connection

For this particular project, the proposed software is National Instrument (NI) LabVIEW version 6.1. This software is compatible with most of the DAQ card available in the market today. For the card, NI PCI-6024E is proposed. This card consists of maximum of 16 analog inputs, two analog outputs, and eight digital input/output for the application. This is sufficient for this particular project. The type of I/O will be determined later. Then, I/Os will be connected to connector block of 68-pin male SCSI-II type, through a cable.

After the materials being identified, the procurement process will begin. Some of the major equipment such as the DAQ cards needs to be bought in front so that its working principle can be tested and understood. Plus, the DAQ cards also need to be posted from oversea vendor because it is not available locally. Other materials for the prototype and electronic circuits can be bought directly from the local stores with ease. After the components arrived or bought, it can be constructed. Under project fabrication, there are two major parts, which are hardware and software. For hardware, the prototype, or the greenhouse will be built from perspex, according to the design decided earlier. It will be the location of the plants and soil. The circuits also will be constructed at this stage. The circuits are mainly for power supply, sensors, output devices and others. The circuits also will be tested to ensure its working as per designed without any failures. Then, the circuits will be placed at its location at the greenhouse. For the software part, the programming parts will be constructed. This is crucial as the programming is the important part of the project, as the program will determine how the sequence of the project, and its working principle.

The program will be tested with simulator, before being hooked-up with the hardware. The integration process need to be carried out as safe as possible. This is because any mistakes during this part can damage either hardware or software (computer). Any leakage of voltage or current after the installation has to be prevented to prevent any unwanted accidents. After that, the testing and commissioning will be conducted to make sure the project communicate well between the hardware and software, and ensure the program is working well after being hooked-up with the hardware. Here, the best parameters for the controllers will be analyzed using numerous methods. From the process reaction curve, several key features can be obtained from the output response. After that, the values of proportional, integral and derivatives gain can be calculated, one of the methods is using Ziegler-Nichols method. Once the values used produced a stable and steady-state response as per desired, the control system is complete. Upon completing this task, the project is ready to be presented.

3.5 Project Milestones

In the project, there are several vital milestones that need extra attention in carry out the tasks. It is essential to avoid any problems with these milestones so it won't affect the project schedule, as per constructed in the Gantt chart shown below, in Figure 6. The important parts of the project are in the designing the project, and also project fabrications. The purchasing of the components such as DAQ card and such are also crucial as the delivery has to be estimated so that the components arrive at least when we need it to be available.

3.6 Gantt Chart

	Task Mode	Task Name	Duration	Start	Finish
1		**Greenhouse Remote Monitoring System**	**158 days**	**Mon 5/21/12**	**Wed 12/26/12**
2		Problems Definition and Project	10 days	Mon 5/21/12	Fri 6/1/12
3		Brainstorming and Feasibility Study	20 days	Sat 6/2/12	Fri 6/29/12
4		**Project Design**	**49 days?**	**Fri 6/22/12**	**Wed 8/29/12**
5		Hardware and Softv	49 days?	Fri 6/22/12	Wed 8/29/12
6		Schematic Drawing	49 days?	Fri 6/22/12	Wed 8/29/12
7		Basic Programming	49 days?	Fri 6/22/12	Wed 8/29/12
8		Procurement of Materials	14 days	Wed 8/29/12	Mon 9/17/12
9		**Project Fabrication**	**44 days**	**Tue 9/18/12**	**Fri 11/16/12**
10		**Hardware**	**44 days**	**Tue 9/18/12**	**Fri 11/16/12**
11		Prototype	44 days	Tue 9/18/12	Fri 11/16/12
12		Electronic Circuits	44 days	Tue 9/18/12	Fri 11/16/12
13		Software	44 days	Tue 9/18/12	Fri 11/16/12
14		Installation and Integration	18 days	Mon 11/19/12	Wed 12/12/12
15		Testing and Commissioning	7 days	Thu 12/13/12	Fri 12/21/12
16		Full Prototype	3 days	Mon 12/24/12	Wed 12/26/12

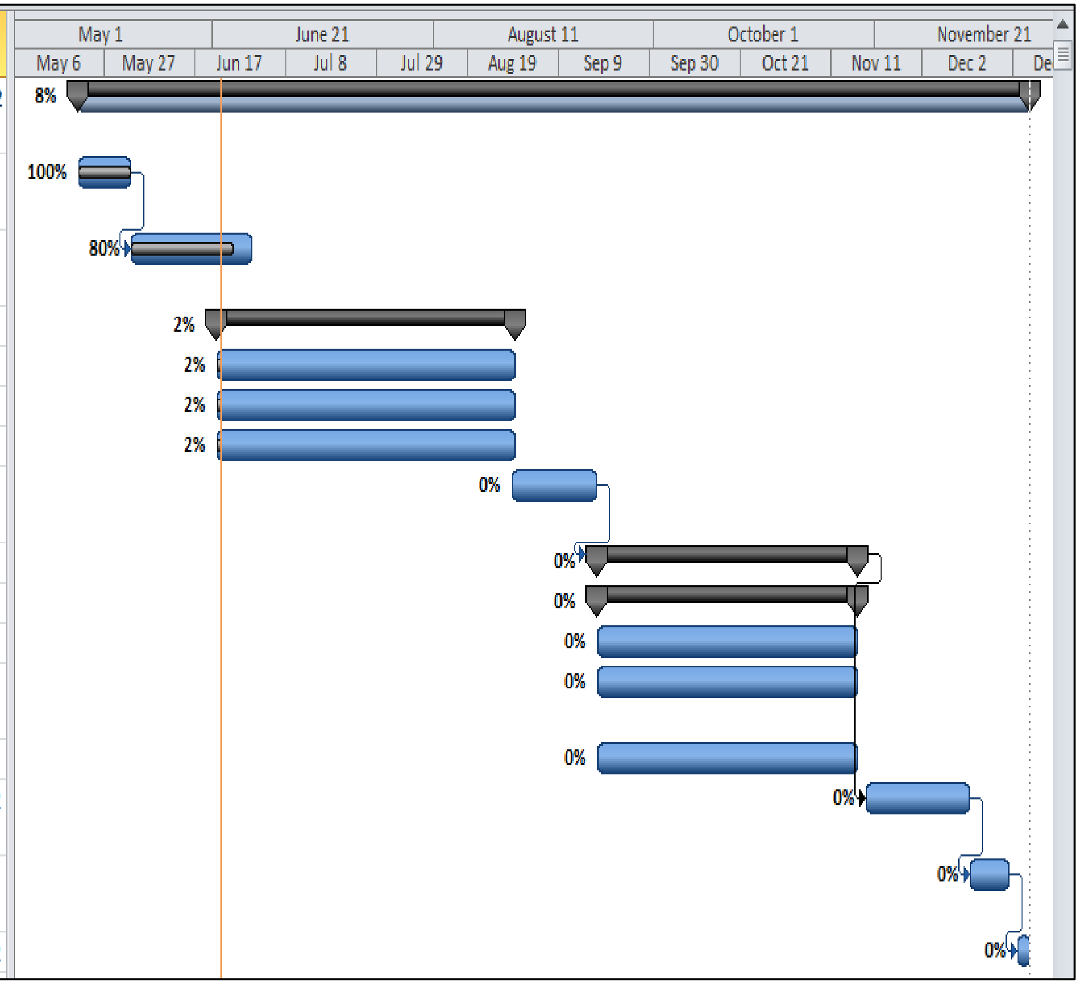


Figure 9: Gantt chart

3.7 Tools Required

In completing the project, various hardware, software and tools are used in assisting the fabrication, in order to produce a project up to the specification desired. The hardware, software and tools used are listed in Table 1, Table 2 and Table 3.

3.7.1 Hardware

Components	Purposes
Perspex	The main structure for the greenhouse.
DAQ Card ***(PCI-6024E)***	The interface device between the hardware and software
Light Dependent Resistor ***(LDR)***	The sensor to measure light intensity.
Precision Centigrade Temperature Sensor ***(LM35CZ)***	The sensor to measure the temperature.
Power Resistor ***(5W 22Ω)***	The heating element for the greenhouse.
Light bulb ***(9V 5W)***	The main source of lighting for the greenhouse. Also act as the control element for the light.
Light Emitter Diode (LED)	The indicator for the greenhouse. Also provide indication for alarm.
Fan	The control elements to regulate the greenhouse's temperature.
DC Power Supply	The main supply for the greenhouse.

Table 1: Hardware for the Project

3.7.2 Raw Materials

Components	Purposes
Soil	The main medium for the plants to grow
Water	The component to provide humidity to the soil.
Seeds	The plants seeds for growing purpose

Table 2: Raw Materials for the Project

3.7.3 Software

Components	Purposes
National Instrument's LabVIEW 6i	The main programming software for the system.
Microsoft Office 2010	The software to complete the documentations

Table 3: Software for the Project

3.8 Project Progress and Next Planning

Upon the completion of the proposal defense presentation, the author has inquired Electrical & Electronics Engineering Department technicians on the availability of the DAQ card. After several discussions, the card was installed in a lab at Block 23 for the author's usage throughout the project. The card was installed complete with the National Instruments LabVIEW version 6i, and the author manages to get a copy of the software to be installed in his own computer. Currently, the author is in the process of getting himself to familiarize with the software itself. Several simple programming techniques learnt and tried using the software with the guides obtained from the internet to be able to know more the software.

As the control loops have been identified, the pre-selection of the components also has been conducted. The components for sensors, final elements, electronic circuits and the prototype itself are chosen based on the requirements and budget. These materials can be changed along the project progressing as if the better alternatives can be found.

Next in the planning for the project is getting the DAQ card to communicate with our programming software. Communication links between these two components is crucial as the transmission of data going in and out of the system is depending on the links. Several internal experiments also will be conducted to determine the correct digital and analog inputs outputs responding well to the software. This will normally takes about 3-4 days to be executed.

Upon establishing the communication links, the details of the programming part for the project will be programmed together with the construction of the electronic circuits. The program is the heart of the project, which will control the project's working operations. After finished with both components, the integration will be conducted between the programming and the circuits. This is to ensure that the correct signals are sent to the correct terminals and vice versa.

Prototype will be constructed at the later stage of the project, and the integrated circuits will be placed inside the prototype. Several arrangements of the materials inside the prototype will be done. After that, the final testing will be conducted before the experiments execution part. The experiments will be done in the final state of prototype, to ensure the results obtained from the experiments are suitable and works well for the prototype conditions.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Data Gathering and Analysis

In this section, the progress of the project will be discussed. The progress will be divided into two parts of the project, which are software and hardware. The hardware and the software sections are constructed individually. Then, these parts will be tested as per real-time simulation. The circuits will be applied with power supplies and the signals of input and output will be tested and measured, as per intended to be working. For the software, simulations will be conducted. Random signals will be applied to the controllers to see the behavior of them, and how they respond to the signals given differences in the controllers' gains.

After these parts completed, they will be integrated together to forms a working prototype. The inputs are connected to the digital and analog input ports, and the digital and analog outputs are connected to the output ports. Power supplies also applied to the final control elements. This is a crucial stage of the project as it will determine the ability of the parts to communicate to each other. The signals sent and received must be correct and accurate. There are settings to be adjusted too in the LabVIEW setting to able the system to receive and send signals correctly.

Then, after making sure that all signals can be sent and received correctly and efficiently, the complete control loops will be tuned before the system can be installed in the application. The ultimate reason for tuning been carried out is to determine the optimum values for the PID controller's parameters to give the users the desired control response. The response shall be stable with no steady-state error, able to give fast response to any changes from the input and the presence of disturbances around the system, with low overshoot.

Lastly, after the controller's parameters have been determine and tested, the system is ready to be applied to the real application.

4.1.1 Hardware

Under the hardware, the project consists of electronic circuit and the green house prototype. For the electronic circuits, all the essential components for the sensors and final control elements circuits have been purchased and tested. This will be discussed more details below.

For the temperature control loop, the sensor and final control element proposed is the thermistor and heating resistor, respectively. For the sensor, there are two options available, thermistor and LM35, a precision centigrade temperature sensor. Each option has its own advantages and disadvantages. While LM35 produce linear output proportional to the temperature measured, thermistor requires the user to refer to tables and have to construct additional circuitry. LM35 also a lot easier to design with the respect to the analog input of the project's DAQCard of PCI-6024E, and have lower output impedance and low power dissipation. NTC-type thermistors produce resistance that is inversely proportional to the temperature measured; hence require the user to add additional programming calculations to interpret the readings given. Hence, this project will use the LM35 as the temperature sensor. Heating resistor of 22Ω 4W will be used as the final control element.

For the circuit construction, the sensor and final control element circuits are according to circuit diagram as Figure 10. LM35CZ, supplied with external voltage of 5 Vdc, responding well to the temperature when heated and cooled. The output is already calibrated in Degree Celsius, and has a linear scale factored of 10 mV every Degree Celsius. Power resistor requires a little extra circuitry. This is because of the analog output of the PCI-6024E can drive a maximum current of only 5 mA. This value is very low and unable to heat up the resistor. The project will use TIP120 an NPN Epitaxial Darlington transistor in order to produce a linear switching application to the resistor.

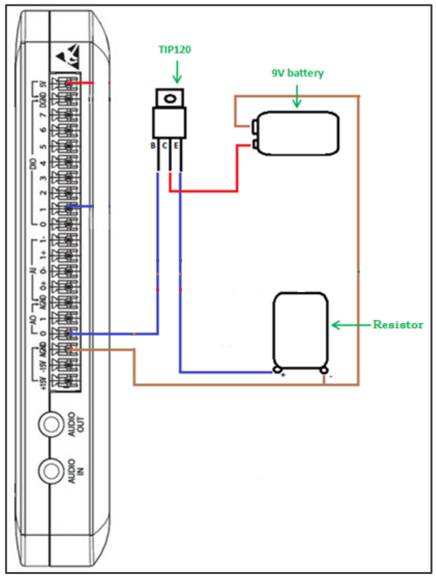


Figure 9: Circuit diagram of power resistor

The base of TIP120 will be connected to the analog output of DAQCard, representing the manipulated value of signal sent from our controller inside the program. Positive side of a 9 Vdc battery will be connected to the collector of TIP120 and the emitter of it will be connected to the heating resistor. The amount of voltage flowing through the resistor is proportional to the amount of signal sent from the controller. This manipulated signal will continuously control the temperature of the heating resistor. The ground of the battery will be connected with the analog ground from the DAQCard.

For the light intensity control, the light dependent resistor (LDR) and a bulb will be used as the sensor and final control element, respectively. This is a common application as per what we have seen in most of the related projects. The LDR, or photoconductive cell used in this project is from VT900 Series. LDR was chosen is because of the reliability of producing good readings and also wide range of capability. For the bulb, a normal 9 V bulb will be used.

For the circuit construction, this application will be using the same circuitry as what we have for the temperature control loop. Replace the LM35CZ with the LDR and the heating resistor with the bulb. The application of this circuit is same, a signal will be sent from analog output to the base of the

TIP120, to control the amount of voltage flowing to the bulb, hence controlling the brightness the bulb itself. Then, the LDR will sense the brightness of the bulb, according to the preset set point, and send the signal back to the controller.

4.1.2 Software

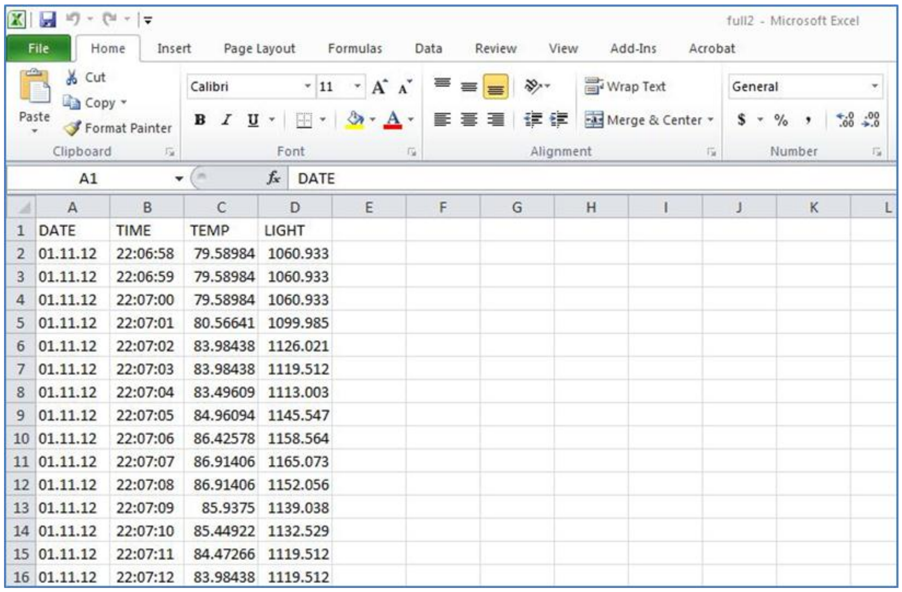
This project's main programme will be based on the National Instrument's LabVIEW version 6.1. This version is the same as per what have been installed in the project's lab to avoid any incompatibility problems to be happened during the integration stage of the project later. The basic with LabVIEW, in the program, there will be two windows that we need to construct our program, which are front panel and block diagram. These windows consist of graphical objects that are the G programming elements. Front panel contains various types of controls and indicators that later will be the interface of the program to the users. Meanwhile, block diagram contains terminals corresponding to front panel controls and indicators, as well as constants, functions, sub-virtual instruments, structures and wires that connect the data from one object to another. Structures are the program control elements.

The control panel of the project can be divided into two parts, temperature control and light intensity control. For the temperature control, we have a temperature chart that will show the trending of the temperature, the set point and the manipulated variable as long as the program is running. There are also two slide rules, one to set the temperature Set Point for the project, and another one is for MV Manual Setting. This slide is for us to manually control the manipulated variable or the amount of signal sent to the heating resistor. This slide also equipped with a manual override button, for us to select to control the variable manually or automatically. There are also three main digital controls for us to set the parameters of proportional, integral and derivatives to our PID Control. There are also digital controls for us to set the high and low limits for the temperature and the update period. The update period is the time the program takes to accept a data, such as 500 milliseconds or 1000 milliseconds or 1 second. There are two indicators that will be turn on during high and low alarms.

While for the light intensity control, there is also a chart to show the live trending of the brightness of the bulb to users, and the digital controls for the PID Control parameters of proportional, integral and derivatives. The Set Point for the light intensity will be set at the Light Set Point knob, while the program also allows manual control on the light intensity through the digital meter. There are also digital displays for the running light intensity, the high and low alarms and the manipulated variable, for the users to see the values of these parameters easily. The start and stop of the program depends on two buttons, which are Run and Stop buttons. These buttons will initiate and halt the program respectively.

For the block diagram of the program, it combines both applications in one control structure. This will ensure that the applications will be operating simultaneously at the same time as the Run button clicked. The main part of the program is the Simple PID blocks, which is the PID Control for the applications in this project. These blocks are the one that receive signals from the sensors, and analyze the signal, based on the preset value of Set Point, before produce a manipulated signal to the final control elements to regulate the process variables. From the block diagram, the Simple PID blocks are connected with various controls and indicators, such as the PID parameters, process variable as the signal for the sensors, set point and upper and lower limits. Output of the Simple PID blocks are connected with charts and indicators as the alarms.

One of the extra features that have been added into the program is the ability of the program to record and save the data inside the program into a Microsoft Excel file. Using a theory called File I/O; this will enable the users to store and retrieve data from files on our computer hard drives. This is done by using several block of File I/O such as File Dialog, New File, Write File and Close File. For this project, the data like the temperature, light intensity, the date and time of the process measured will be recorded into an Excel file. This is to facilitate the users to track back records of the process to analyze and improve the performance and also rectify any problems that may occur. Figure 11 below is the example of an Excel file, resulted from the experimentation using our block diagram.



	DATE	TIME	TEMP	LIGHT
2	01.11.12	22:06:58	79.58984	1060.933
3	01.11.12	22:06:59	79.58984	1060.933
4	01.11.12	22:07:00	79.58984	1060.933
5	01.11.12	22:07:01	80.56641	1099.985
6	01.11.12	22:07:02	83.98438	1126.021
7	01.11.12	22:07:03	83.98438	1119.512
8	01.11.12	22:07:04	83.49609	1113.003
9	01.11.12	22:07:05	84.96094	1145.547
10	01.11.12	22:07:06	86.42578	1158.564
11	01.11.12	22:07:07	86.91406	1165.073
12	01.11.12	22:07:08	86.91406	1152.056
13	01.11.12	22:07:09	85.9375	1139.038
14	01.11.12	22:07:10	85.44922	1132.529
15	01.11.12	22:07:11	84.47266	1119.512
16	01.11.12	22:07:12	83.98438	1119.512

Figure 10: Data logging in Microsoft Excel file

4.2 Experimentation / Modelling

Each of the circuits constructed were tested its capability to function as intended before being permanently soldered to a printed circuit board. The testing was conducted by constructing the circuits using a breadboard, before applied with suitable power supply and manipulates the circuit as per the real applications.

For the sensor circuits, the testing was conducted by applying 5Vdc to the sensor and manipulates them using the process variables. For example, the temperature circuit using LM35CZ was tested with a heated resistor and the output of the sensor was measured. The output voltage regulated as the temperature increased and later decreased in the range of 0.2 V to 1.5 Vdc.

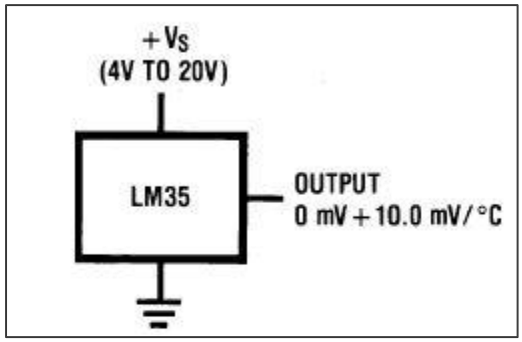


Figure 11: Basic centigrade LM35 sensor

The light intensity application's sensor was also tested using the same method, by applying supply of 5 Vdc. The principle of operation is the resistance of LDR will vary as the lighting is applied to its surface. The resistance will regulate the amount of voltage drop across the LDR, hence a suitable relationship between the light brightness and the voltage signal sent to the programme. With these expected results, both circuit can be apply to the DAQCard.

For the output circuits, the experiment was conducted also in the same method for final control elements, heating resistor and bulb. By using TIP120 to regulate the supply to the control elements, the 1-10 Vdc variable voltage was applied to the base of the transistor to see the changes to the control elements. The heating resistor's temperature was increased and decreased was the variable voltage was going upscale and downscale respectively. The bulb's brightness also regulated as we varies the manipulated voltage to the transistor. Several important parameters were measured during the experiments.

Manipulated Voltage (V)	Voltage Supply (V)	Emitter Voltage (V)	Emitter Current (mA)	Remarks
1.0	9.7	0.34	4.66	no light
2.0	8.99	1.10	48.8	
3.0	8.44	2.09	75.9	min. bright
4.0	7.73	2.86	96.28	
5.0	7.15	3.84	115.5	
6.0	6.5	4.99	133.3	normal
7.0	6.24	5.90	145.4	
8.0	7.10	6.50	160.67	
9.0	8.16	7.48	174.0	
10.0	9.1	8.43	188.0	max bright

Table 4: Result of bulb experiment

Results tabulated in Table 4. As the manipulated variable increases, the amount of voltage and current flowing into the bulb via the emitter of the transistor is increases and the bulb produces more light. The manipulated voltage is the voltage that will be produced by the DAQCard as per signal sent from the PID Control. The results prove that manipulating signal from the DAQCard can vary the brightness of the bulb according to the signal sent from the controller. This satisfactory result confirms that the circuits are working perfectly and can be integrate with the DAQCard later.

4.3 Prototype

A greenhouse prototype of the project will be built to replicate the real life application of the greenhouse control and monitoring remote system. The house will be built of persepx, an acrylic glass as plastic material that easy to cut and put up together as per plan. The combination of several parts of the house will be done by using plastic glue. The prototype, as per depicted in Figure 13 and 14, will be built once the integration stage of the circuits with the DAQCard completed and passed. This is to ensure that the circuits will functioning perfectly once installed in the house, to avoid any hassle of troubleshooting the circuit later. The house will be built as per plans below.

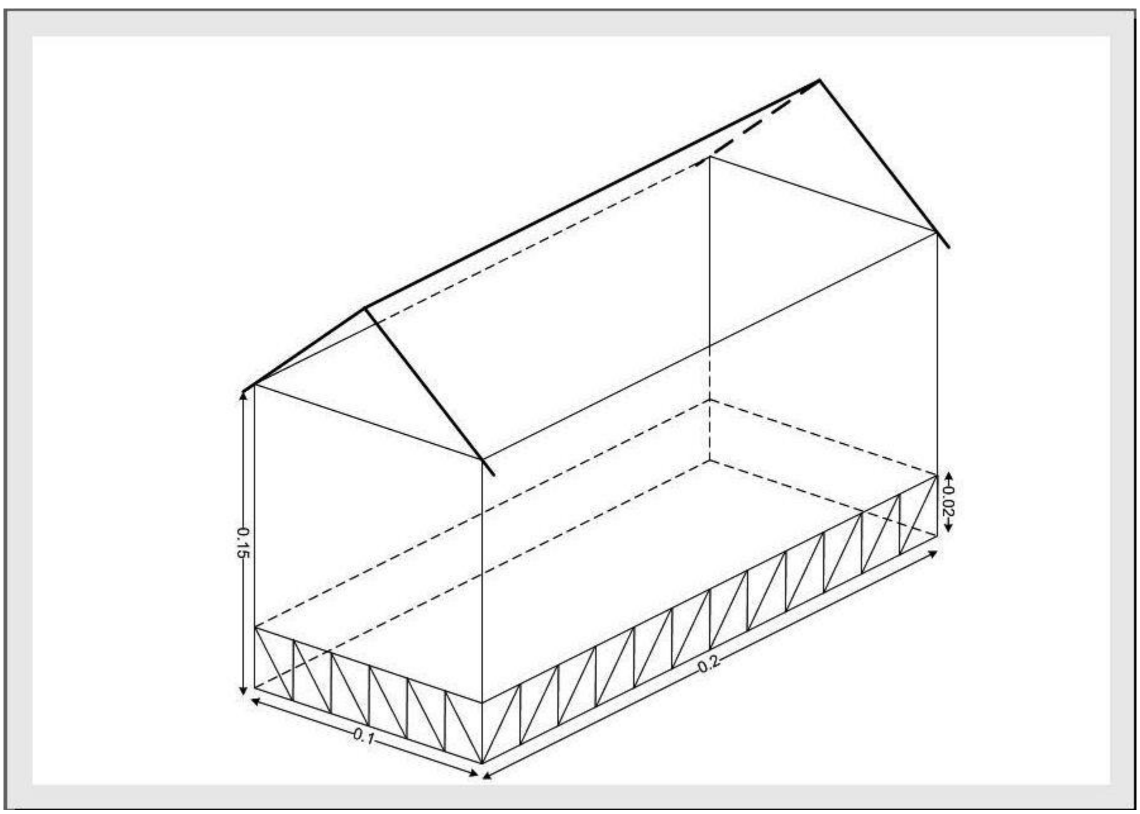


Figure 12: Isometric plan

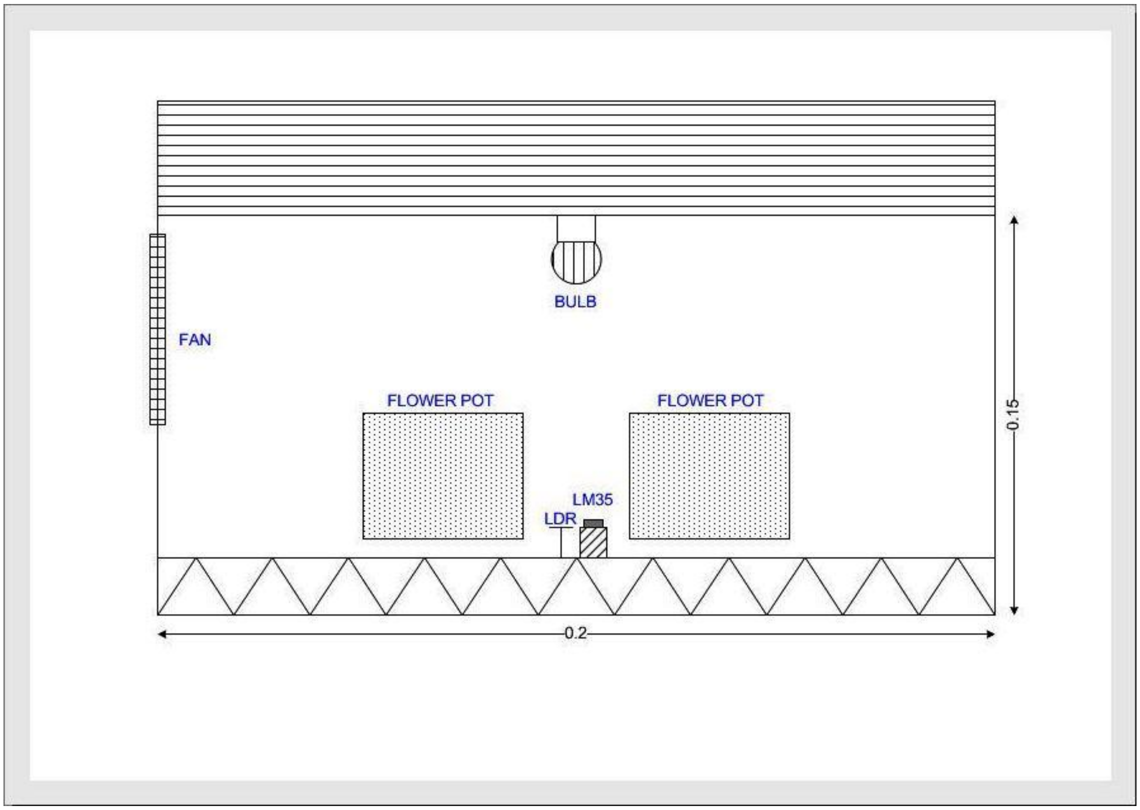


Figure 13: Side view

The placement of the sensors with respect of the final control elements are made to make the sensors can detect changes from the control elements effectively. LM35CZ placed right at the heating resistor, in order for the sensor to quickly sense the temperature changes and send signal to the controller. Temperature is a very slow process so this configuration can save us time to see the application works. The LDR are located right below the bulb, so that any changes in the brightness of the bulb can be quickly detected by the LDR. The fan is included for two factors. One is in automatic mode; the fan will turn on once the temperature rise above the high alarm set point. This is to facilitate the decreases of the room temperature faster. Other is the fan can be turn on manually to provide disturbance to the temperature control application. Here, the capability of the temperature controller to control the temperature under the influence of the disturbance can be seen. The analysis of this factor will be made later in the Result and Discussion.

4.4 Control Loops Tuning

Both temperature and light intensity control loops will be tuned to ensure the controllers can meet up the objective of regulates the process efficiently and effectively.

4.4.1 Temperature control loop

For the temperature control loop tuning, two methods will be applied to determine the best response as temperature is a crucial part of the system itself. First method is Ziegler-Nichols method and another one is Cohen-coon method.

Ziegler-Nichols was developed by John G. Ziegler and Nathaniel B. Nichols. Under this method, there is another two ways to be applied. The first one is the open-loop tuning method. As per its procedure attached in the Appendix A, this method conducted when the temperature at a steady-state and control loop in an open-loop configuration. A step function step is applied from the output signal of the controller. This signal will increase the amount of heat released from the final control element. The change in the temperature sensed by the temperature sensor and will be received by the controller. The resulting response from the sensor will be recorded and analyze to determine its specific characteristics such as dead time, rise time, input state change and the output state change. The resulting response is as per Figure 15 below.

Figure 14: Process reaction curve for temperature control

From the response obtained, its characteristics extracted, calculated and tabulated as per Table 1 below.

Measurement	Value
Change in perturbation / *MV, σ*	30
Change in output / *PV, Δ*	28
Maximum slope, *S*	0.075
Apparent dead time, *ɵ*	30s
Calculations	**Value**
Steady-state process gain, *Kp= Δ / σ*	0.933
Apparent time constant, *T= Kp / s or T=1.5*$(t_{0.63\Delta} - t_{0.28\Delta})$	12.44
Fraction dead time, R= *ɵ / T*	2.41

Table 5: Ziegler-Nichols Open Loop method data

These data then will be used to calculate the gains for the controllers before being applied and tested. Based from the correlation given in the procedures, the resulting calculations for the gains are show in Table 6.

	K_c	T_i	T_d
P	5.54	0	0
PI	4.98	99	0
PID	6.64	60	15

Table 6: Controller's parameter from Ziegler-Nichols Open Loop

Each of the controller modes of P-only, PI, and PID will be tested against the surrounding to obtain the responses to allow us to know the best parameters for the applications. The responses are as follows.

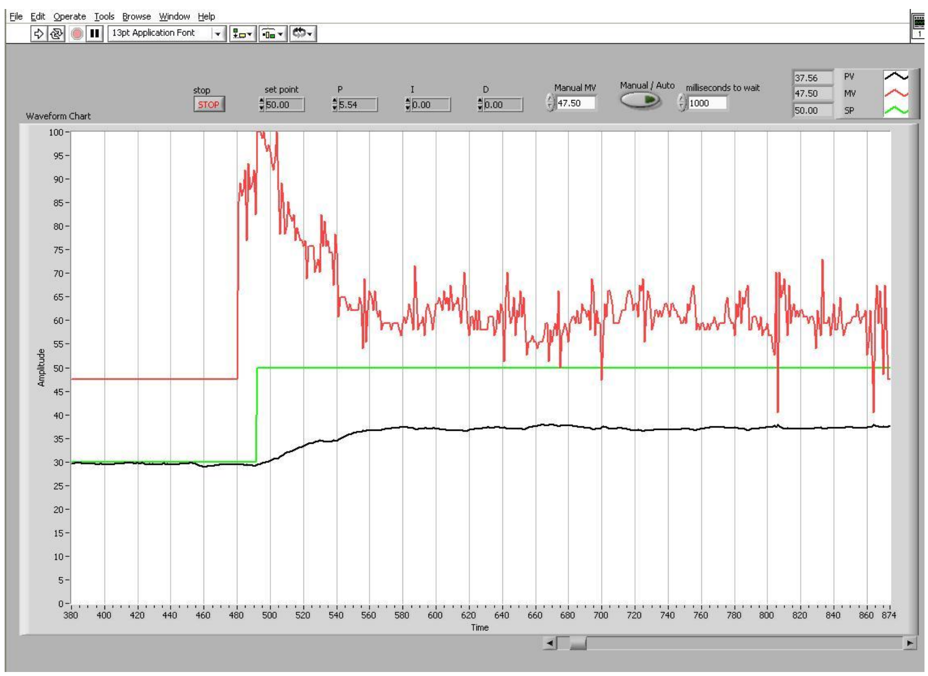


Figure 15: Ziegler-Nichols Open Loop P-only mode

Figure 16 shows the P-only mode of controller with Ziegler-Nichols Open Loop method. The response is having a large steady-error, which is about 15 Degree Celcius. The manipulated variable from the controller was not able to increase the temperature up to the setpoint.

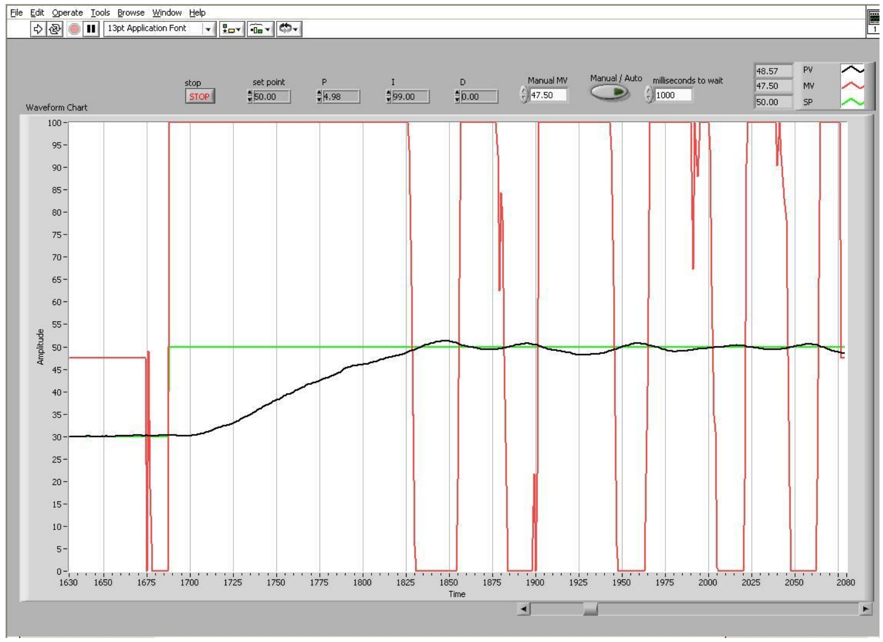


Figure 16: Ziegler-Nichols Open Loop PI mode

In Figure 17, the PI-mode of controller producing a stable response, with it stabilizes around the setpoint given as the controller manages to keep it close to the setpoint. The response takes 130 seconds to settles and having low overshoot, thus producing low steady-state error.

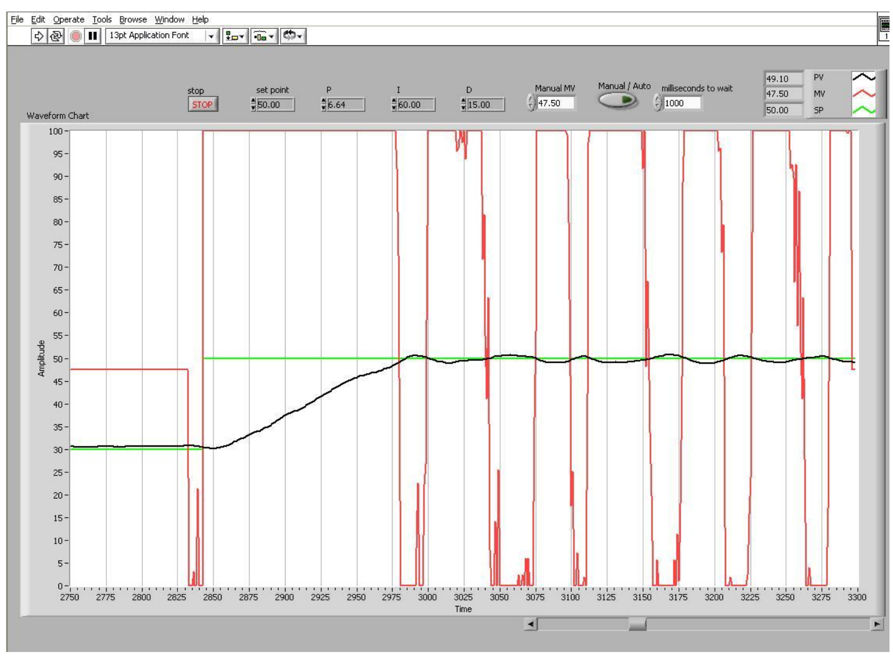


Figure 17: Ziegler-Nichols Open Loop PID mode

For Ziegler-Nichols Open Loop in PID-mode in Figure 18, the process response produces also stable with minimum steady-state error due to the low overshoot compare to the PI-mode of controller, albeit it takes longer time before settling around the setpoint, which is about 150 seconds.

Cohen-coon method suits the slow and stable response given from the Ziegler-Nichols methods. This method practically used for the first-order models with time delay because of the controller does not response simultaneously to the changes in the input given by the sensor. It also often categorized as an offline method. Calculation-wise, this method requires extra calculation to be made. The formulas to determine the controller's gains are as per in the tuning procedure attached in Appendix A. The calculations results are listed in Table 7.

	K_c	T_i	T_d
P-only	4.05	0	0
PI	2.48	19.53	0
PID	4.35	43.18	7.59
PD	3.71	0	1.21

Table 7: Controller's parameter from Cohen-coon

Each of the m odes parameter then being plugged into the controller and the output responses were produced and analyzed to determine the best parameters for the intended applications.

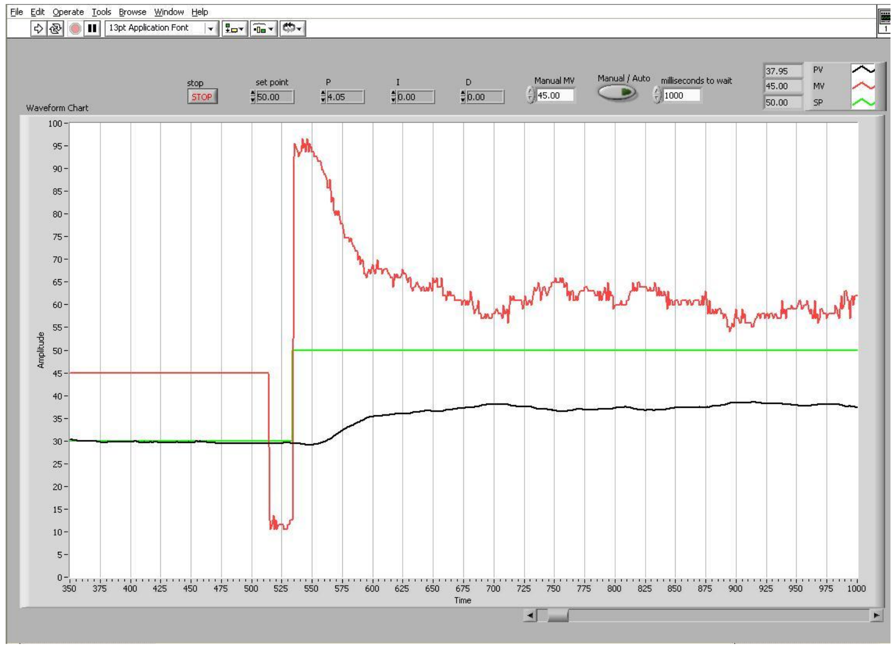


Figure 19: Cohen-Coon P-only mode

With Cohen-Coon of P-mode controller shown in Figure 19, the response stabilizes with large steady-state error produced. The difference between the setpoint and the process variable is about 13 Degree Celcius. This is a quite large error as the temperature needs to be close to the setpoint.

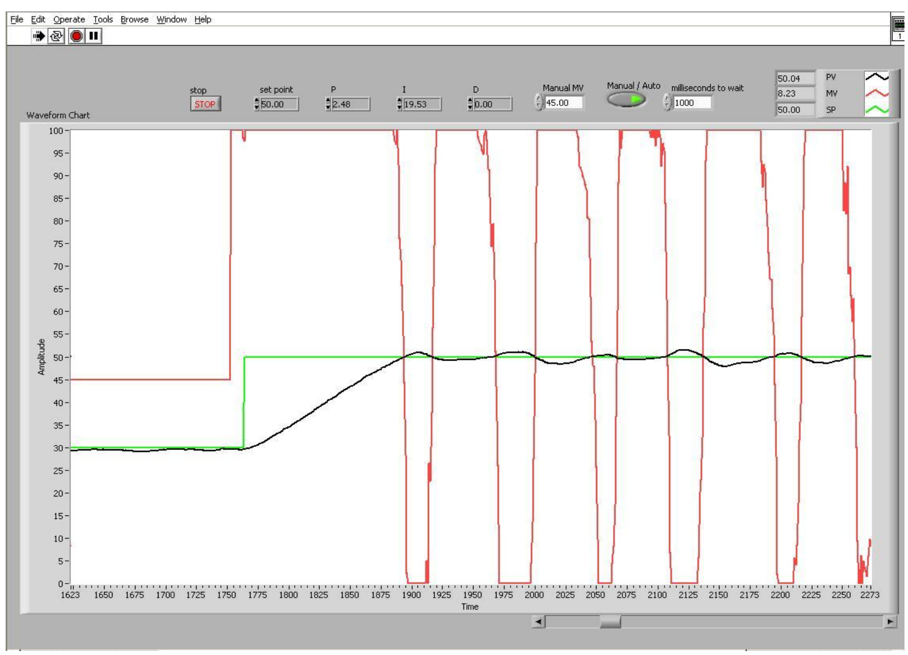


Figure 18: Cohen-Coon PI mode

Figure 20 shows the process response with the PI-mode controller applied to the system. The response produced contains low overshoot and oscillates around the setpoint, hence have a minimal steady-state response. The time taken to settles is around 125 seconds.

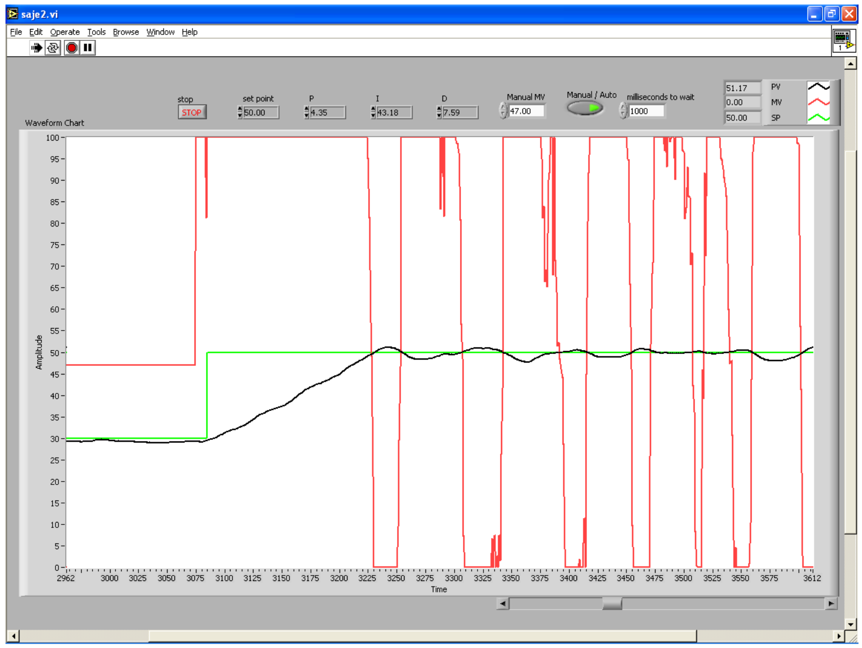


Figure 19: Cohen-Coon PID mode

For Cohen-Coon PID-mode as shown in Figure 21, the output response is quite stable around the setpoint, with low overshoot and low average steady-state error. It takes longer time than PI-mode controller to settles, about 140 seconds.

Figure 20: Cohen-Coon PD mode

For the controller with PD-mode, it's producing a constant steady-state error, as shown in Figure 22. The error is rather larger compared to P-only mode, with the difference being 16 Degree Celcius.

From the experiments that have been carried out, with all the results being calculated and analyzed, the best parameters for the temperature control loop is PI-mode of controller from the Cohen-Coon method. It has shortest settling time among all, meaning that this controller produces response that quick to resolve at the setpoint. This mode of controller is also able to produce response with minimal overshoot, and able to keep the process stable after steady state response. For PID-mode controllers, it still producing satisfies results but with approximately longer time to settles compare to the PI-mode of controllers. The P-only and PD modes from both methods are producing constant error, hence not meeting the important requirements and objectives of the project.

4.4.2 Light intensity control loop

For the light intensity control loop tuning, we applied the controller using Ziegler-Nichols closed-loop method. In this particular method, we will need to determine the correct gain and period for the response for the P-only controller applied. Hence, from the value of the gain and period, the parameters for the controller can be determine from simple calculations.

During the experiment to tuning the light intensity controller been carried out, it is found out that the controller cannot control the loop accurately. The manual type of control produce normal results as the output can be manipulated manually ranging from 0% (fully close) to 100% (fully open) the final control element (bulb). Once the mode of controller changes to automatic to tune the controller, the output of it just goes up and down, causing the bulb to be in off and on conditions throughout the experiment. The response captured in Figure 23 below.

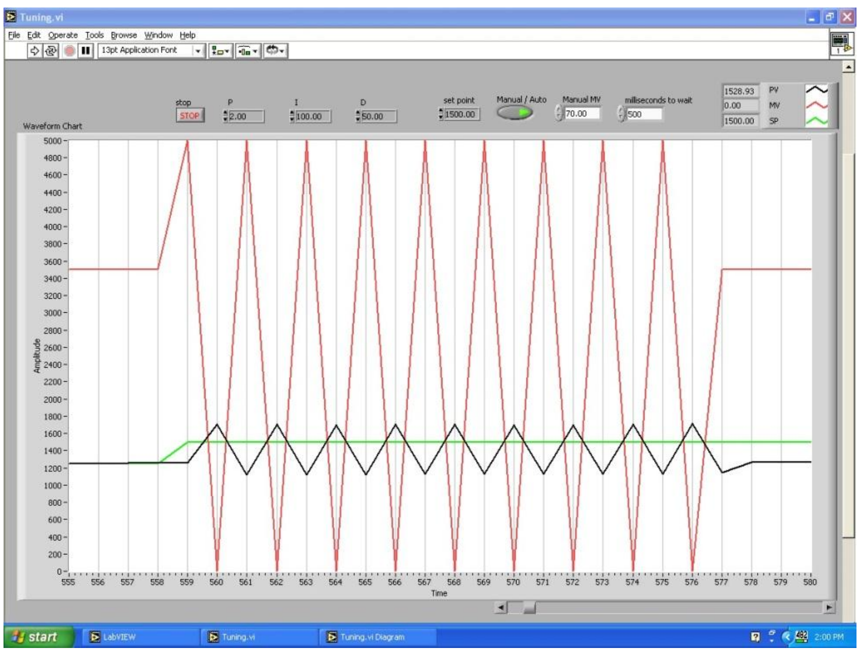


Figure 21: Response from light intensity control tuning

Further analysis on the response was implemented to investigate and clarify the causes of this kind of response from the controller. From the response, the author noted that the response by the sensor was delayed by a certain period. This means that LDR detected the signal from the bulb and sent it to the controller after the bulb changes it conditions. From this analysis, the pre-findings can be assumed that either the sensor was too slow or the controller produced signal instantly upon receiving the signal from the sensor.

Another type of control methods is via trial and error. This type of tuning method is based on the guess and checks by the tuner, and sometimes carried out to fine-tuning the controller after obtained calculated parameters, or as the last resort, when other methods fail to produce acceptable results. In this method, normally the proportional gaine (P), acted as the main control on the controller, while Integral (I) and Derivative (D) times refine the response. These three parameters values will be change accordingly in order to produce desired result. After the method being implemented, the responses fail to be improved and the control loop is still uncontrollable.

Due to the time constraints and few problems encountered, the author decided to change the control mode of this loop from continuous PID control to On/Off controller. The mode of operation is the set point is maintained at a 750 Lux, which is the intensity of light at dawn. Once the intensity of the light goes below the set point, the controller will automatically turn on the bulb. Then, when the intensity goes above the set point, the bulb will be turned off. This mode of operation's objective is to give the source of light to the crops and plants during the night time.

4.5 Problems Encountered and Countermeasures

During construction of the project, from the first stage to the end, various problems encountered. These problems sometimes minor but sometimes can be major ones can determine the successful of a project. Under this part, the problems found and solutions to the problem is recorded to show the ability of the students to find ways to resolve any hazards along with the completion of a project.

The first major problem was the inability of the DAQCard PCI6024E analog output port to power up big element by itself. This is due to the limitation of the port. Analog output from the card only able to supply up to 10mA of current to the load, which is not enough to power the final control elements, 5W 22Ω of power resistor and 5W 9V of bulb. The solution is the application of darlington transistor of TIP120. This transistor will be driven by the signal from the analog output to switch the external power supply (9V battery) to the final control elements. So, the directly proportional relationship between the signals of analog output to the current transferred to the control elements suits our application perfectly.

Another problem is with the signal received from the temperature sensor LM35. The range of the signal from the sensor is 0 - 2 Vdc, whereas the range of the analog input it's connected to is -5 – 5 Vdc with 12 bits of resolution. With the resolution, the accuracy of the analog-to-digital converter (ADC) of the DAQCard is 2.442 mV, while the sensor output will change for 10 mV for every 1 Degree Celcius. So, the analog input resolution is quite sensitive compared to the signal from the sensor. This resulting for the graph of the temperature sensor gets choppy and not constant at all along the measurement to be made. This signal will affect the entire program as this signal will be sent to the controller, hence influencing the signal output from the controller, manipulated variable. The solution is to take the average reading from the sensor before being sent to the controller. This will stabilize the input signal while still producing reliable reading to the system. This stable signal will also stabilize the signal from the controller too.

One of the other major problems is that the inability of the PID controller to properly control the light intensity of the bulb. This problem may cause the hysteresis of the controller itself. The restraint is on the LabVIEW version 6 software-based PID controller itself with very limited capabilities that might be the reason of the problem. Solution chosen for this problem is the control method change to the on/off control method to achieve the objective of providing the plants and crops inside with best condition.

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

The control system of a greenhouse is very important feature in developing crops and plants whether in small-scale or big-scale productions. Farmers nowadays realize that the investment in the control system can substantially reduce the operation and production costs when it's been manage optimally. With the control system, manpower is no longer required heavily as what we have seen before. More, the efficiency and reliability of the system also much better that the error-prone manpower. In short, the objectives of this project were met.

The working principles of a greenhouse have been studied thoroughly to further preparing the control system that up to the standard required. Control system must be suitable for the Malaysia's whether and able to grow crops in Malaysia environment. With the scope of the control system focuses more on the temperature and light intensity control systems, major parameters were continuously measured and monitored so that the relationships of these parameters can be analyzed and the performance of the system can be improved based on the results and log data acquired later. The continuous control of temperature control will regulate the temperature inside the greenhouse for the plants conditions even with the present of the disturbances in the system. The on/off control light intensity control will produces sufficient level of luminous for the plant's photosynthesis process. These two parameters are important and cannot be neglected in the control system performance for the greenhouse.

For recommendations in the future, the limitations of budget and time constraint prevent the author to apply some features into the system. These features is added value into the system and with them, the control system is more complete and complex. The performance of the control system also will improve significantly with these features.

More linear control processes can be added into the system such as the humidity control, air circulation control, light intensity, pH for the water, water level and carbon dioxide, CO_2 control. These processes are influencing the productivity of the crops in one way or another. Continuous control on these processes will enhance the productivity of the plants and also its quality.

Wireless sensors application can be applied to this system. With wireless sensors, they have no hassle of cables from the control system to the sensors, and mobile. Mobility enables the sensors to be replaced in other location within the distance limit with ease. New devices also can be installed, added to the network without having to re-route any cables from the control system too. This installation is easy and requires minimum maintenance.

The control system also can be made accessible from anywhere with the ability of internet. The LabVIEW program can be connected with the internet and local networks. With the LabVIEW's built in web server, the system's front panels can be publish in to the web. This will allow user to access the system even not being near the greenhouse.

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APPENDICES

ZIEGLER-NICHOLS CLOSED-LOOP METHOD FOR LIGHT INTENSITY CONTROL LOOP

A. Controller Tuning using Ziegler-Nichols Closed Loop Method

- **i.** At the Light Intensity Controller faceplate, set it to **Manual** mode and closed the manipulated variable (MV) to 0 %.
- **ii.** Set the Controller Gain (P) to 0.5, the Integral time (I) to 0/9999, and the Derivative time (D) to 0.
- **iii.** Manually increase the value of MV to 70 %.
- **iv.** At the Controller faceplate, adjust the Set Point (SP) to 1250 Lux.
- **v.** Slowly adjust the value of MV to bring the process variable (PV) to almost equal to the SP.
- **vi.** Observe the PV from the graph window and wait until it has stabilized to a constant value.
- **vii.** Set the controller to **Auto** mode. Wait until the PV to stabilize.
- **viii.** Make a small step change to the SP by increasing it to 1500 Lux.
- **ix.** Observe the PV from the graph window. If the PV response is not oscillatory, set the controller back to Manual mode, double to controller gain (P) value and repeat from step **viii.** to **x.** until PV becomes oscillatory.
- **x.** If the PV response is oscillatory, observe whether the magnitude of PV is increasing or decreasing.
  - If it is increasing, reduce the controller gain by 1.5 times.
  - If it is decreasing, increase the controller gain by 1.5 times.

    Aim to obtain an oscillatory response with almost constant amplitude. The controller gain (P) needed to achieve such conditions is the **ultimate gain, K_u**.
- **xi.** When constant amplitude is achieve, allow up to 3 or more oscillation cycles to be recorded and freeze the graph window.
- **xii.** The average period of an oscillation is the **ultimate period, P_u**.

B. Tabulation and Calculation of PID Controller Parameters

i. Using the graph obtained earlier, note down the ultimate gain, Ku and determine the ultimate period, Pu. Tabulate your results using table below.

Measurement	Value
Ultimate Gain, K_u	
Time for 3 oscillation periods	
Calculations	**Value**
Ultimate Time, P_u	

ii. Based on the Ziegler-Nichols closed loop tuning correlations, calculate the controller tuning parameters based on the formulas in table below.

C. Control Loop Performance Test

i. At the Light Intensity Controller faceplate, set it to **Manual** mode and closed the manipulated variable (MV) to 0 %.
ii. Ensure that the controller tuning parameters have been set. Use the parameters obtained from the calculations, and start with P-only controller.
iii. Manually increase the value of MV to 50 %.
iv. At the Controller faceplate, adjust the Set Point (SP) to 1100 Lux.
v. Slowly adjust the value of MV to bring the process variable (PV) to almost equal to the SP.
vi. Observe the PV from the graph window and wait until it has reasonably stabilized to a constant value.
vii. Set the controller to **Auto** mode. Wait until the PV to stabilize.
viii. Change the controller SP to 1500 Lux
ix. Observe the PV from the graph window and look for some typical response characteristics (oscillations, overshoot, offset, etc).
x. Capture the important process responses (transient and steady-state) and continue with the next controller's parameter.

Control Modes	Parameters
P only	$K_C = \left(\frac{1}{RK_p}\right)\left(1+\frac{R}{3}\right)$
P + I	$K_C = \left(\frac{1}{RK_p}\right)\left(\frac{9}{10}+\frac{R}{12}\right)$
	$T_I = \theta\frac{(30+3R)}{(9+20R)}$
P + I + D	$K_C = \left(\frac{1}{RK_p}\right)\left(\frac{4}{3}+\frac{R}{4}\right)$
	$T_I = \theta\frac{(32+6R)}{(13+8R)}$
	$T_D = \theta\frac{4}{(11+2R)}$
P + D	$K_C = \left(\frac{1}{RK_p}\right)\left(\frac{5}{4}+\frac{R}{6}\right)$
	$T_I = \theta\frac{(6-2R)}{(22+3R)}$

ZIEGLER-NICHOLS OPEN-LOOP METHOD FOR LIGHT INTENSITY CONTROL LOOP

A. Pressure Process Model Identification using Step Response Testing

i. At the controller faceplate, set the Set Point (SP) to 30 Degree Celsius. Then set the controller to Auto mode. See that it is able to control its temperature properly using the trend graph in the faceplate.

ii. At the controller faceplate, manually set its manipulated variable (MV) to 20%.

iii. Observe the reaction curve of the process from the graph and wait until it has stabilized to a constant value.

iv. Manually increase the MV by an additional 10%.

v. Observe the reaction curve from the graph window and wait until it has stabilized to a constant value, than freeze the graph. This is the process reaction curve (PRC).

vi. Compare and match the curve with a set of expected process reaction curve provided.

vii. Make several measurements as per the chart. Tabulate your results using table below.

Measurement	Value
Change in perturbation / MV, σ	
Change in output / PV, Δ	
Maximum slope, S	
Apparent dead time, θ	
Calculations	**Value**
Steady State Process Gain, $K_P = \Delta / \sigma$	
Apparent time constant, $\tau = K_P / S$ or $\tau = 1.5(t_{0.63\Delta} - t_{0.28\Delta})$	
*Fraction dead time, $R = \theta / \tau$	

* *The fraction dead time mentioned here is slightly different than one being used for Ciancone correlations.*

Control Modes	Parameters
P only	$K_C = \left(\frac{1}{RK_p}\right)\left(1+\frac{R}{3}\right)$
P + I	$K_C = \left(\frac{1}{RK_p}\right)\left(\frac{9}{10}+\frac{R}{12}\right)$
	$T_I = \theta\frac{(30+3R)}{(9+20R)}$
P + I + D	$K_C = \left(\frac{1}{RK_p}\right)\left(\frac{4}{3}+\frac{R}{4}\right)$
	$T_I = \theta\frac{(32+6R)}{(13+8R)}$
	$T_D = \theta\frac{4}{(11+2R)}$
P + D	$K_C = \left(\frac{1}{RK_p}\right)\left(\frac{5}{4}+\frac{R}{6}\right)$
	$T_I = \theta\frac{(6-2R)}{(22+3R)}$

B. Control Loop Performance Test

- **i.** Make sure that the SP on the controller faceplate is set at 1200 Lux and the controller is set at Auto mode. Wait for the response to a constant value.
- **ii.** At the controller faceplate, set it to Manual mode. Key in the tuning parameters obtained earlier, one mode at a time.
- **iii.** Adjust the SP to 1300 Lux.
- **iv.** Adjust the controller output (MV) until its process value (PV) is close to its SP.
- **v.** Set the controller to Auto mode.
- **vi.** Observe the PV curve from the graph window and wait until it has reasonable stabilized to a constant value.
- **vii.** Change the controller SP to 1500 Lux.
- **viii.** Observe the PV curve and look for some typical response characteristics such as oscillations, overshoot, offset and etc.
- **ix.** Capture the important process responses.

National Semiconductor

November 2000

LM35
Precision Centigrade Temperature Sensors

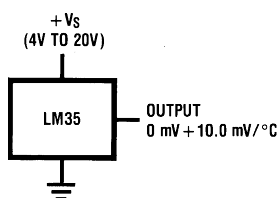
General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ˚ Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼˚C at room temperature and ±¾˚C over a full −55 to +150˚C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1˚C in still air. The LM35 is rated to operate over a −55˚ to +150˚C temperature range, while the LM35C is rated for a −40˚ to +110˚C range (−10˚ with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

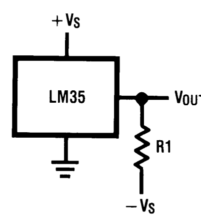
- Calibrated directly in ˚ Celsius (Centigrade)
- Linear + 10.0 mV/˚C scale factor
- 0.5˚C accuracy guaranteeable (at +25˚C)
- Rated for full −55˚ to +150˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08˚C in still air
- Nonlinearity only ±¼˚C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications



DS005516-3

FIGURE 1. Basic Centigrade Temperature Sensor (+2˚C to +150˚C)



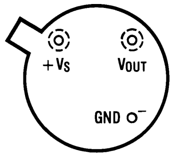
DS005516-4

Choose $R_1 = -V_S/50\ \mu A$
V_{OUT}=+1,500 mV at +150˚C
= +250 mV at +25˚C
= −550 mV at −55˚C

FIGURE 2. Full-Range Centigrade Temperature Sensor

Connection Diagrams

TO-46
Metal Can Package*

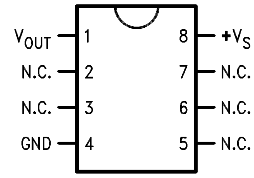


BOTTOM VIEW
DS005516-1

*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

SO-8
Small Outline Molded Package

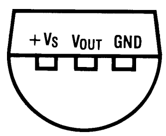


DS005516-21

N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

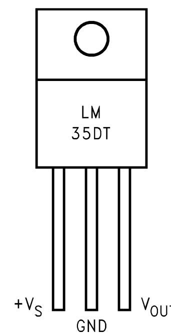
TO-92
Plastic Package



BOTTOM VIEW
DS005516-2

Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

TO-220
Plastic Package*



DS005516-24

*Tab is connected to the negative pin (GND).
Note: The LM35DT pinout is different than the discontinued LM35DP.

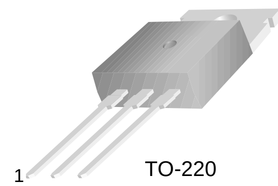
Order Number LM35DT
See NS Package Number TA03F

FAIRCHILD
SEMICONDUCTOR ™

TIP120/121/122

Medium Power Linear Switching Applications

- Complementary to TIP125/126/127



TO-220

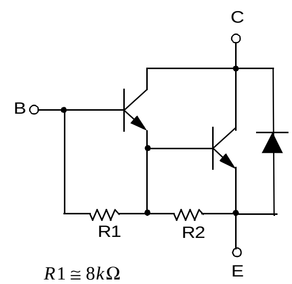
1.Base 2.Collector 3.Emitter

NPN Epitaxial Darlington Transistor

Absolute Maximum Ratings T_C=25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : TIP120 : TIP121 : TIP122	60 80 100	V V V
V_{CEO}	Collector-Emitter Voltage : TIP120 : TIP121 : TIP122	60 80 100	V V V
V_{EBO}	Emitter-Base Voltage	5	V
I_C	Collector Current (DC)	5	A
I_{CP}	Collector Current (Pulse)	8	A
I_B	Base Current (DC)	120	mA
P_C	Collector Dissipation (T_a=25°C)	2	W
P_C	Collector Dissipation (T_C=25°C)	65	W
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	- 65 ~ 150	°C

Equivalent Circuit



$R1 \cong 8k\Omega$
$R2 \cong 0.12k\Omega$

Electrical Characteristics T_C=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Max.	Units
V_{CEO}(sus)	Collector-Emitter Sustaining Voltage : TIP120 : TIP121 : TIP122	I_C = 100mA, I_B = 0	 60 80 100		 V V V
I_{CEO}	Collector Cut-off Current : TIP120 : TIP121 : TIP122	 V_{CE} = 30V, I_B = 0 V_{CE} = 40V, I_B = 0 V_{CE} = 50V, I_B = 0		 0.5 0.5 0.5	 mA mA mA
I_{CBO}	Collector Cut-off Current : TIP120 : TIP121 : TIP122	 V_{CB} = 60V, I_E = 0 V_{CB} = 80V, I_E = 0 V_{CB} = 100V, I_E = 0		 0.2 0.2 0.2	 mA mA mA
I_{EBO}	Emitter Cut-off Current	V_{BE} = 5V, I_C = 0		2	mA
h_{FE}	* DC Current Gain	V_{CE} = 3V,I_C = 0.5A V_{CE} = 3V, I_C = 3A	1000 1000		
V_{CE}(sat)	* Collector-Emitter Saturation Voltage	I_C = 3A, I_B = 12mA I_C = 5A, I_B = 20mA		2.0 4.0	V V
V_{BE}(on)	* Base-Emitter ON Voltage	V_{CE} = 3V, I_C = 3A		2.5	V
C_{ob}	Output Capacitance	V_{CB} = 10V, I_E = 0, f = 0.1MHz		200	pF

* Pulse Test : PW≤300µs, Duty cycle ≤2%

Typical characteristics

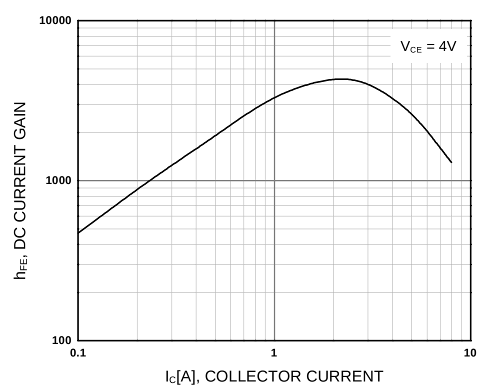


Figure 1. DC current Gain

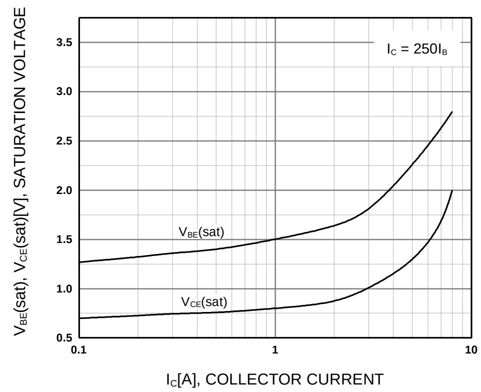


Figure 2. Base-Emitter Saturation Voltage Collector-Emitter Saturation Voltage

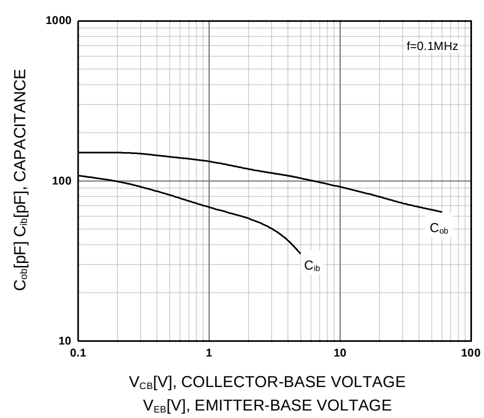


Figure 3. Output and Input Capacitance vs. Reverse Voltage

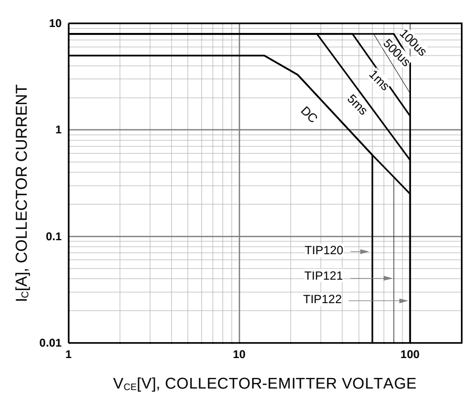


Figure 4. Safe Operating Area

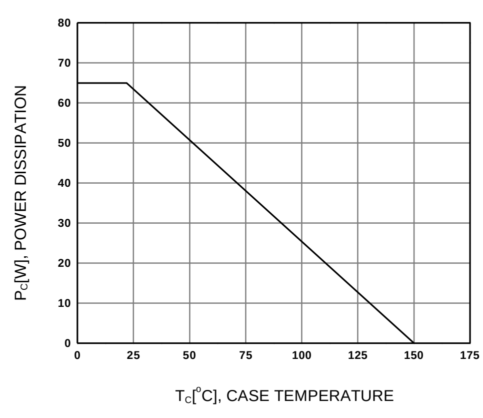
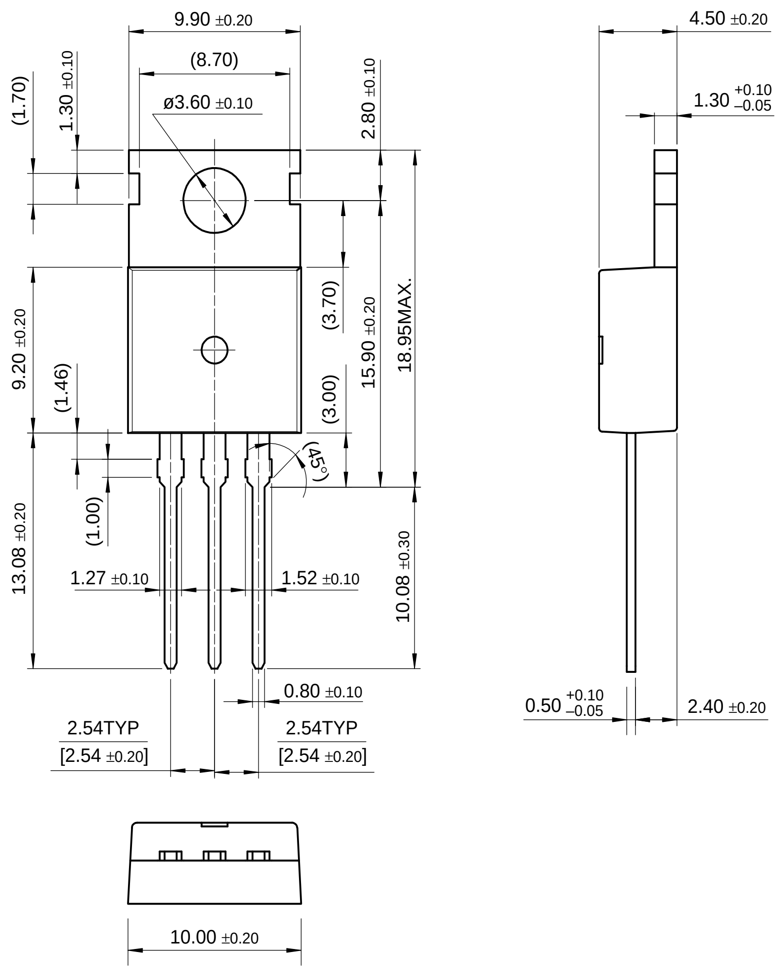


Figure 5. Power Derating

Package Demensions

TO-220



Dimensions in Millimeters

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Definition of Terms

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